

6.2.3 HIGHER MENTAL FUNCTIONS PROJECT

Modeling of Higher Mental Functions

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I) Summary of Research Program

A. Technical Goals:

There are three technical goals of the Higher Mental Functions Project:

- (1) To improve and "therapeutically" experiment with a computer simulation of paranoid processes in order to make treatment recommendations to clinicians based on experience with the model.
- (2) To develop a new taxonomy of psychiatric patients based on the conceptual patterns appearing in accounts of their illnesses.
- (3) To develop an intelligent speech prosthesis for patients suffering from communication disorders.

B. Medical Relevance and Collaboration:

The Higher Mental Functions Project is located in the Neuropsychiatric Institute at UCLA. The medical relevance of its research concerns the fields of psychiatry and neurology. The Project collaborates with clinicians and investigators in psychiatry, neurology, the neural sciences and neurolinguistics.

C. Progress Summary:

We have improved the paranoid model to the point where it can be utilized for therapy experiments. (The model has now passed a true Turing Test in which it cannot be distinguished from real patients.)

The taxonomy effort is just under way, using the language recognition program which serves as the front end of the paranoid model. This program will have to be added to and modified to serve the purpose of finding and classifying the conceptual patterns appearing in patients' accounts of their illnesses.

We have interfaced a micro-processor with a voice-synthesizer to provide a speech prosthesis for patients unable to speak. The next step is to write an "intelligent" algorithm which attempts to figure out what the patient is trying to say from his partial input information.

II. Interactions with the SUMEX-AIM Resource

A. Collaborations:

The project collaborated with Professor Jon Heiser, Department of Psychiatry, University of California, Irvine, and consulted with Professor Robert K. Lindsay, Department of Psychology, University of Michigan, in conducting a Turing Test of the paranoid model. Other users of SUMEX have received advice and suggestions regarding their problems as well as opportunities to contrast their simulations with ours. We have benefitted greatly from others' comments on the adequacy and inadequacy of our paranoid model.

B. Sharing, etc.:

Members of the project have participated in two workshops held at Rutgers, presenting several papers, chairing panels, and conducting discussion groups. Informal discussions with large numbers of workers in Artificial Intelligence in Medicine have led to a helpful sharing of ideas and techniques. SUMEX is valuable to us as a communication channel combining the advantages of a telephone and the U.S. mail without the disadvantages of either. For widely scattered researchers, it facilitates the intimate, low-level communication which is normally accomplished in hallways or around water coolers. The individual discussions are not very profound, but the cumulative effect subtly improves our research.

The existence of SUMEX as an independent project naturally relieves numerous researchers of the burden of separately financing and staffing a large computer facility.

D. Up-to-date List of Publications:

- Colby, K.M., Parkison, R.C. and Faught, B. Pattern-matching Rules for the Recognition of Natural Language Dialogue Expressions. Am. J. Computational Linguistics, Microfiche 5, Sept., 1974.
- Colby, K.M. Clinical Implications of A Simulation Model of Paranoid Processes. Archives of General Psychiatry, 33, 854-857, 1976.
- Faught, W., Colby, K.M. and Parkison, R.C. Inferences, Affects and Intentions in A Model of Paranoia. Cognitive Psychology, 9, 153-187, 1977.
- Colby, K.M. An Appraisal of Four Psychological Theories of Paranoid Phenomena. J. of Abnormal Psychology, 86, 54-59, 1977.
- Parkison, R.C., Colby, K.M. and Faught, W.S. Conversational Language Comprehension Using Integrated Pattern Matching and Parsing. Artificial Intelligence (In Press) 1977.
- Colby, K.M., Christinaz, D. and Graham, S. A Computer-driven, Personal, Portable and Intelligent Speech Prosthesis for Aphasic Disorders. Brain and Language (In Press) 1977.
- Colby, K.M. On the Way People and Models Do It. Perspectives in Biology and Medicine (In Press) 1977.

Heiser, J., Colby, K.M., Faught, W. and Parkison, R.C. Testing Turing Test (Forthcoming).

Faught, W.S. Conversational Action Patterns in Dialogs. Proceedings of the Workshop on Pattern-directed Inference Systems, May, 1977.

6.2.4 INTERNIST PROJECT

INTERNIST - Diagnostic Logic Project

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I. SUMMARY OF RESEARCH PROGRAM

A. Objectives

The principal objective of this research project has been and continues to be the development, evaluation, and implementation of a computer-based diagnostic consultation system for internal medicine. This work, which was initiated at the University of Pittsburgh approximately six years ago, has been supported for the past three years by a grant from the Bureau of Health Resources Development. A heuristic diagnostic program called INTERNIST has been developed, along with an extensive medical database now comprising more than four hundred disease categories and two thousand manifestations of disease. The system has been tested with a wide variety of difficult clinical problems: cases published in the medical journals, CPC's, and other interesting and unusual problems arising in the local teaching hospitals. In the great majority of these test cases, the heuristic INTERNIST program has proved to be effective in sorting out the pieces of the puzzle and coming to a correct diagnosis. In some cases, as many as six distinct disease entities have been identified correctly.

We believe that by the time of the expiration of the BHRD grant in June, 1977, our original objective, which was to develop a system providing expert diagnostic capability with regard to the major diseases of internal medicine, will have been accomplished to the extent possible in the current laboratory framework.

At that time, we propose to initiate a broader collaboration, which will invite the participation of remote users in

- (a) further evaluation of the INTERNIST programs and data-base.
- (b) development of specialized data-bases and procedures for various medical subspecialties.
- (c) refinement of the user interface.
- (d) investigation of alternate uses of the INTERNIST data-base.

We believe that the expansion of the experience base of INTERNIST users, which will result from this type of collaboration, will significantly enhance the further course of INTERNIST development.

B. Progress Summary

Expansion of the medical data-base to encompass new areas of disease is an on-going activity of the project. Much of this work is carried out by medical students who elect to take part in the project as part of their fourth year clinical rotation, with the period of participation varying from 6 to 18 weeks.

Each student is assigned a group of diseases, usually in a specific clinical area, for study. The literature on a disease is studied exhaustively for all quantitative data available. Frequently clinical experts on the faculty are consulted, particularly about controversial data. The student compiles a complex list of the manifestations of the disease under study and assigns tentative measures of strength of association.

The clinical principal investigator together with any other clinicians working on the project then review the data exhaustively in order to assure the appropriateness and completeness of the disease profile.

The profile is then entered into the computer and tested for completeness and reliability against a typical or "textbook" example of clinical cases. If available, other cases of the disease from the floors of our university hospital and from published cases such as the clinical-pathological conferences from the New England Journal of Medicine and the American Journal of Medicine are also used. Further refinement occurs in the course of the continued use of the data-base.

In addition to this data-base development, work on a refined diagnostic program has also been an on-going activity during this period.

The present INTERNIST process employs a 'problem - formation' heuristic, which identifies one of perhaps several problems in a clinical case as its initial focus of problem-solving attention. Although only one problem is considered at a time, the process recycles after each problem is solved, thereby uncovering the entire complex of diseases present. In the great majority of clinical cases tested, this strategy of iterative problem formation and solution has proved to be effective in sorting out the complexities of a case and rendering a correct diagnosis. In many respects, however, it seems clear that performance could be significantly enhanced if the program were to attend to the various component problems and their inter-relationships simultaneously. Use of a more global problem - formation strategy could be expected to yield more rapid convergence on the correct diagnosis in many cases, and in at least some cases to prevent missed diagnoses.

Alternative problem formation strategies that exploit the type of pseudoparallel processing facilitated by the INTERLISP 'spaghetti stack' are presently being investigated. We believe that this research will also set the stage for subsequent development of a therapeutic management component of the INTERNIST consultation facility; however at the present time it is not possible to project a precise timetable for the development of these additional capabilities.

C. Publications

1. Pople, H.E., Myers, J.D., & Miller, R.A., "The DIALOG Model of Diagnostic Logic and its use in Internal Medicine". Proceedings of the Fourth International Joint Conference on Artificial Intelligence, Tbilisi, USSR, September 1975.
2. Pople, H.E., "Artificial-Intelligence Approaches to Computer-based Medical Consultation, Proceeding IEEE Intercon, New York, 1975.
3. Pople, H.E., "The Syntheses of Composite Hypotheses in Diagnostic Problem Solving: An Exercise in Hypothetical Reasoning". Proceedings of the Fifth International Joint Conference on Artificial Intelligence, August 1977 (forthcoming).

II. INTERACTION WITH SUMEX-AIM RESOURCE

A. Medical Use of Programs and Collaborations

Because of the research and development nature of our work on the INTERNIST system over the past several years, we have been somewhat limited in our ability to establish wide-spread collaborations. However, members of the medical house staff in the local hospitals having some prior experience with the project have continued to work with INTERNIST while pursuing their medical training. In addition, project staff often have occasion for interaction with individuals and groups who have interest in the characteristics of the diagnostic system from both medical and computer science perspectives. Future plans for more extensive collaboration are discussed in section III.

B. AIM Interactions

We have benefitted considerably from interactions with other members of the SUMEX-AIM community. In June '76 we participated in the AIM workshop at Rutgers, which provided an excellent perspective as to what else is going on in the field. During the past several months we have had useful exchanges with Randy Davis, Victor Yu, and John Foy, three individuals participating in the MYCIN project. In addition, we rather routinely interact with SUMEX staff regarding fine points and problems relating to our use of system facilities.

The opportunity to keep abreast of developments in a fast changing field is one of the principal benefits to be derived from the collegial environment fostered by SUMEX-AIM.

6.2.5 MEDICAL INFORMATION SYSTEMS LABORATORY

MISL - Medical Information Systems Laboratory

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University of Illinois at Chicago Circle

I) SUMMARY OF RESEARCH PROGRAM

A.) TECHNICAL GOALS

The Medical Information Systems Laboratory (MISL) was established under grant HM-0114 in Chicago to pursue three activities: i) Construction of a database in ophthalmology, ii) Clinical knowledge system support, and iii) Network-compatible database design. Priorities in year 04 of MISL's operation are the same as in previous years: investigations into how to construct a database in ophthalmology, and into distributed database design, are ancillary to the exploration of a clinical knowledge system to support clinical decision making. We are developing ways to get reliable clinical information into the ophthalmic database primarily because we are interested in getting out significant clinical decision support.

B) APPROACH AND MEDICAL RELEVANCE

B.1) Construction of the database in Ophthalmology

A specific aim of this project is to construct a workable database in ophthalmology, using the outpatient population of the Illinois Eye and Ear Infirmary. We view this database as a testbed for developing clinical decision support systems. The Ophthalmology Department of the Illinois Eye and Ear Infirmary provides an excellent environment for evaluating new techniques for capturing and using clinical information.

B.2) Clinical knowledge support system

The goals for clinical knowledge system development are to provide a flexible user interface for a prototype relational database system, to devise means of accessing alphanumeric and pictorial information stored in the database system, and to provide efficient means for logically restructuring a database so that it can be adapted to different operating environments in a network-compatible distributed medical information network.

No clinical database, however, has intrinsic significance beyond its ability to support the diagnosis and management of disease. Additional goals for the clinical knowledge system are therefore to devise computer-based consultation systems for glaucoma and selected retinal/choroidal diseases, and to provide

formal models which permit the relational development and evaluation of rule-based consultation systems containing 2,000 - 10,000 rules. In recognition that a continuum exists between physician-guided decision support and computer-based consultation, we choose to describe these services as a Clinical Knowledge System: a consortium of a clinical database and rules for its interpretation.

C) PROGRESS SUMMARY (INCLUDING ITEMS OF INTEREST TO SUMEX-AIM COMMUNITY ONLY)

C.1) The database in ophthalmology

Physician terminals and interfaces to ophthalmic instruments have been positioned in the general eye clinic and several key ophthalmic subspecialty clinics. Systematic, modular hardware and software for clinical source data acquisition have been established. The clinical support system computer will shortly be transferred to the newly dedicated Goldberg Research Center, adjacent to the Illinois Eye and Ear Infirmary. We look forward to stabilizing the hardware configuration, telecommunication linkages and software support.

C.2) Clinical knowledge system support

C.2.a) Development of the relational database includes the following:

- A user interface through which unsophisticated users communicate with the database.
- An intelligent coupler that serves as an intermediary between the end user and the distributed database system. The coupler listens to the user's retrieval requests; helps the user formulate his requests correctly; efficiently translates user's retrieval requests into a network-compatible retrieval command language; and obtains authorization from the system for data retrieval and/or update.
- Tools for picture data management. Graphical indexing techniques are provided so that the clinical researcher and physician can easily retrieve pictorial/graphical information from the medical database.
- Means for logical database synthesis. This involves conversion of the user's view of the database into a logically coherent physical organization.

C.2.b) Development of a computer-based consultation system for diagnosis and management of glaucoma.

This involves on-going collaboration between Dr. Jacob Wilensky at MISL, and, through SUMEX-AIM, other investigators around the United States. Included are the original investigators in glaucoma consultation: Dr. Casimir Kulikowski (Rutgers), Dr. Shalom Weiss (Mt. Sinai Hospital, NY), and Dr. Aaron Safir (Mt. Sinai Hospital).

C.2.c) Development of a consultation system for diagnosis and management of retinal/choroidal diseases.

A design has been proposed (in Walser and McCormick, see below) for MEDICO, a consultation system that advises non-expert physicians in the management of chorioretinal diseases. In addition, a major subsystem of MEDICO, responsible for mediating the acquisition and organization of rules, has been implemented.

C.2.d) Formal models for consultation systems.

Petri nets have been studied, primarily by Murata (see below), as a formal representation for interacting parallel processes. Petri nets are similar to causal networks, as described by Kulikowski and Weiss at Rutgers, except that, with Petri nets, cyclic activity is easily represented. The similarity between Petri nets and inference nets has also been noted (Walser and McCormick). The utility of the Petri net framework for modelling physical processes was explored by Walser, with the construction of a simulated coffee maker. Further studies are planned.

D.) LIST OF MISL PUBLICATIONS

- Chang S. K., Donato N., McCormick B. H., Reuss J., and Rocchetti R. (1977) A relational database system for pictures. Proc. IEEE Workshop on Picture Data Description and Management, April 20-22, 1977, Chicago, Illinois.
- Chang S. K. and Cheng W. H. (1976) A database skeleton and its application to logical database synthesis. MISL report M.D.C. 1.1.17.
- Chang S. K. and McCormick B. H. (1975) An intelligent coupler for distributed database systems. MISL report M.D.C. 1.1.7.
- Malone, J. E. (1976) Interval generalization of structure representation. MISL report M.D.C. 1.1.22.
- Malone J. E. (1975) User's guide to uniclass cover synthesis. MISL report M.D.C. 4.4.1.
- Malone J. E. (1975) Addendum to AQVAL/1 (AQ7), part 1: User's guide and program description. MISL report M.D.C. 4.4.1.
- Manacher G. K. (1977) The case for strong loops and selection structures in ordinary computer languages. MISL report M.D.C. 1.1.21.
- Manacher G. K. (1975) On the feasibility of implementing a large relational data base with optimal performance on a minicomputer. Proc. International Conference on Very Large Data Bases, Framingham, Mass.
- McCormick B. H. and Nordmann B. J. Jr. (1977) Modular asynchronous control design. Forthcoming in IEEE Transactions on Computers. Also MISL report M.D.C. 1.1.25.

- McCormick B. H. and Amendola R. C. (1977) Cytospectrometers for subcellular particles and macromolecules: design considerations. Presented at Workshop on Theory, Design and Biomedical Applications of Solid State Chemical Sensors, Case Western Reserve University, March 23-30, 1977. Also MISL report M.D.C. 1.1.24.
- McCormick B. H. and Wilensky J. (1975) Clinical knowledge acquisition: design of a relational data base in ophthalmology. Proc. Second Annual Medical Information Systems Conference, Urbana, Ill.
- McCormick B. H., Goldberg M. F., and Read J. S. (1974) Clinical decision-making: design of a data base in ophthalmology. Proc. First Annual Medical Information Systems Conference, Urbana, Ill.
- Michalski R. S. and Chang S. K. (1976) A self-model for a relational database. MISL report M.D.C. 1.1.16.
- Michalski R. S. (1975) On the selection of representative samples from large relational tables for inductive inference. MISL report M.D.C. 1.1.9.
- Murata T. (1976) On liveness and other properties of E-Nets. MISL report M.D.C. 1.1.15.
- Murata T. (1976) Bibliography on Petri nets and related topics. MISL report M.D.C. 1.1.20.
- Murata T. (1976) A method for synthesizing marked graphs from given markings. Presented at 17th Annual Symposium on Foundations of Computer Science, October 25-27, Houston, Texas.
- Murata T. (1976) On deadlock and the liveness of E-nets. Presented at the 17th Annual Symposium on Foundations of Computer Science, October 25-27, Houston, Texas.
- Murata T. (1975) State equation, controllability, and maximal matchings of Petri nets. MISL report M.D.C. 1.1.10.
- Murata T. and Church R. W. (1975) Analysis of marked graphs and Petri nets by matrix equations. MISL report M.D.C. 1.1.8.
- Vere S. A. (1975) Induction of concepts in the predicate calculus. Proc. Fourth IJCAI.
- Vere S. A. (1975) Relational production systems. Forthcoming in Artificial Intelligence. Also MISL report M.D.C. 1.1.5.
- Walser R. L. and McCormick B. H. (1976) Organization of clinical knowledge in MEDICO. Proc. Third Illinois Conference on Medical Information Systems, Urbana, Ill.
- Walser R. L. and McCormick B. H. (1977) A system for priming a clinical knowledge base. Forthcoming in Proc. 1977 National Computer Conference, June 13-16, Dallas, Texas.

II) INTERACTION WITH SUMEX-AIM RESOURCE

A.) COLLABORATION

Major collaboration at present is through the ONET, involving the ophthalmology departments of five medical schools. Dr. Jacob Wilensky is actively engaged in evaluating and modifying the Glaucoma Consultation Program, written originally by Shalom Weiss.

6.2.6 RUTGERS COMPUTERS IN BIOMEDICINE

Rutgers Research Resource - Computers in Biomedicine

Principal Investigator: Saul Amarel
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I) SUMMARY OF RESEARCH PROGRAM

A) Goals and Approach

The fundamental objective of the Rutgers Resource is to develop a computer based framework for significant research in the biomedical sciences and for the application of research results to the solution of important problems in health care. The focal concept is to introduce advanced methods of computer science - particularly in artificial intelligence - into specific areas of biomedical inquiry. The computer is used as an integral part of the inquiry process, both for the development and organization of knowledge in a domain and for its utilization in problem solving and in processes of experimentation and theory formation.

The Resource community includes 48 researchers - 30 members, 8 associates and 10 collaborators. Members are mainly located at Rutgers. Collaborators are located in several distant sites and they interact, via SUMEX-AIM, with Resource members on a variety of projects, ranging from system design/improvement to clinical data gathering and system testing. At present, collaborators are located at the Mt. Sinai School of Medicine, N.Y.; Washington University School of Medicine, St. Louis, Mo.; Johns Hopkins Medical Center, Baltimore, Md.; Illinois Eye and Ear Infirmary, Chicago, Ill.; and the University of Miami.

Research in the Rutgers Resource is oriented to "discipline-oriented" projects in medicine and psychology, and to "core" projects in computer science, that are closely coupled with the "discipline-oriented" studies. Work in the Resource is organized in three AREAS OF STUDY; in each area there are several projects. The areas of study and the senior investigators in each of them are:

- (1) Medical Modeling and Decision Making (C. Kulikowski, A. Safir).
- (2) Modeling Belief Systems and Common-sense Reasoning (C.F. Schmidt, N.S. Sridharan).
- (3) Artificial Intelligence: Representations, Reasoning and System Development (S. Amarel)

In addition, the Rutgers Resource is sponsoring an Annual National AIM Workshop, whose main objective is to strengthen interactions between AIM activities, to disseminate research methodologies and results, and to stimulate collaborations and imaginative resource sharing within the framework of AIM. The second AIM Workshop was held near the New Brunswick Rutgers Campus on June 1-4, 1976. The third Workshop is scheduled for July 6-8, 1977.

B) Medical Relevance; Collaborations

A major part of our research is focusing on the development of computer based medical consultation systems. We are using artificial intelligence approaches in problems of: knowledge acquisition from experts in a medical specialty and from their clinical experience; the representation and management of these complex and changing data bases of medical knowledge within the computer; and the development of a sufficiently rich repertoire of reasoning strategies for diagnosis, prognosis, therapy selection, explanation and teaching. By linking such a system to a data base of prospectively chosen cases, we are in the position to provide a powerful tool for clinical research with built-in interpretative capabilities.

Our approach emphasizes the development and application of clinically useful models that describe the pathophysiology and dysfunction of diseases in a variety of tasks:

- a) Consultation embodying expert knowledge, which is expressed in terms acceptable to the clinician;
- b) Clinical research aid, assisting the investigator to;
 - i) Summarize and incorporate his knowledge, experience, and opinions into a computer system;
 - ii) Analyze his data, check it against that of other investigators, pooling it when appropriate to draw stronger conclusions based on the large sample of cases;
 - iii) Test, evaluate and modify the data base of models and decision strategies to produce an up-to-date summary of experience in his specialty.
- c) Screening and diagnosis, to aid nursing or paramedical personnel in performing routine decision procedures within restricted medical environments;
- d) Instruction to provide practitioners and support personnel with appropriate explanation and guidance in clinical decision-making.

A unique and novel aspect of our work is the creation of a network of clinical investigators to collaborate on the testing and continued development of the computer programs needed to accomplish the above tasks. During 1976, the ophthalmological network (ONET) of glaucoma investigators has grown and established itself, with several significant collaborative research projects currently underway. The consultation program for glaucoma using the causal associational network (CASNET) model developed within the Rutgers Resource, was jointly presented by the ONET members at the 1976 meeting of the Association for Research in Vision and Ophthalmology. An important new emphasis has been the incorporation into the consultation program of alternative expert opinions on subjects currently under debate. Dr. Douglas Anderson of the Bascom-Palmer Eye Institute at the University of Miami has joined ONET to provide such alternatives and strengthen the glaucoma model in certain important areas. The SUMEX-AIM shared computer resource has been essential to the activities of ONET.

The knowledge base and the strategies of our CASNET glaucoma consultation system are being strengthened and refined continuously in the ONET environment. The system is now at a point where it is considered by leading ophthalmologists as "highly competent to expert" in several subspecialties of glaucoma. The ONET group was confident enough about the system to demonstrate it at the October 1976 meeting of the American Academy of Ophthalmology and Otolaryngology. The reactions to the system were most favorable. The response of an independent sample of ophthalmologists taken at this meeting strongly emphasized the importance of the system for glaucoma research.

In addition to the main glaucoma research activities, the Resource has collaborated with the Mt. Sinai-Rutgers Health Care Computer Laboratory in the development of models for refraction and visual fields. These will be used by clinical prototype programs for guiding paramedical personnel in data acquisition and decision-making. These programs run on the PDP-11 computers of the clinical ophthalmological system at Mt. Sinai, which are to be linked to the PDP-10 at Rutgers for accessing the more complex models of disease when they are needed. The activities in conjunction with the Health Care Computer Laboratory reflect the more applied aspects of our work in the medical area.

The collaboration with Dr. R. Nordyke of the Straub Clinic on thyroid disease consultation systems has continued at a low level of activity during 1976.

In the area of Belief Systems, collaboration has continued with Professor Andrea Sedlak and her group at the University of North Carolina. This collaboration is focusing on developmental aspects of action perception.

In the AI Area we had extensive interactions with researchers in several institutions on problems of representation, problem solving systems, natural language processing, automatic programming, data base systems, and interactive systems. Contacts continued with the natural language group at BBN (Woods, Bruce) on the design of natural language processors for medical systems. Also, we had contacts with the Stanford-Xerox group (Winograd, Bobrow) which is involved in the development of KRL (Knowledge Representation Language).

Following the Rand Workshop on Biomedical Modeling (February 18-20, 1976), in which S. Amarel participated, preliminary contacts started with Dr. D. Garfinkel from the University of Pennsylvania in connection with possible applications of AI methods to the modeling of metabolic processes.

Our close contacts with the Stanford projects on Heuristic Programming (Drs. Buchanan, Feigenbaum, Lederberg) are continuing. The orientation and approach of these Stanford projects are very similar to ours. We continue to share with the investigators in DENDRAL and METADENDRAL a strong interest in computer-based methods of scientific inference and in AI ideas and techniques for representation of knowledge in computers, diagnostic problem solving and theory formation.

One of the significant collaborative developments this period was the joint work of Ed Feigenbaum and his students at Stanford, and Saul Amarel and his students at Rutgers, on the development of an AI Handbook. This handbook is being prepared on the SUMEX-AIM and RUTGERS-10 computers, and it is intended to

provide a network-accessible encyclopedic coverage of the AI field for the AIM community and AIM guests.

C) Progress Summary

1. Areas of Study and Projects

a) Medical Modeling and Decision-Making

The consolidation of the ophthalmological network (ONET) of collaborating glaucoma investigators using the SUMEX-AIM shared resource facility, the testing and improvement of the CASNET consultation system with the help of the collaborators, the design and implementation of a time-oriented database system and a set of analysis programs for aiding joint clinical research activities within ONET, and the development of a new knowledge-based consultation system (IRIS), represent the main achievements in the last year.

The network of investigators in glaucoma is designed to foster development of consultation systems that embody sufficient depth for knowledge and expert opinion in a variety of subareas to be useful as research and teaching tools. The collaborative activities, coordinated by Dr. A. Safir at Mt. Sinai, bring together selected scientist-users with complementary interests and strengths in different aspects of glaucoma, and Resource investigators who are concentrating on the development of new computer science methodologies in modeling and problem solving. During this period, there has been more extensive testing of the CASNET glaucoma consultation program. The collaborators had several meetings to discuss the structure of the glaucoma model and suggested many improvements and additions. A significant new capability of the program is the inclusion of alternative interpretations that capture differences of opinions among the experts on aspects of the model that are currently under debate.

A new development during this period has been the implementation of a time-sequenced data base for glaucoma, which has the dual purpose of aiding the clinical research of ONET collaborators and of providing a systematic means for evaluating and improving the performance of the consultation programs.

In the area of general methods and systems we have developed a multilevel-semantic network representation for characterizing disease processes, their anatomical descriptions and their taxonomic identification. This is used by a set of normative rules for diagnostic, prognostic and therapeutic reasoning, which results in a very general and flexible system for clinical consultation. A prototype model called IRIS is being developed using the glaucoma knowledge-base. We have also continued our investigations of other representation paradigms: a frame-based approach and the relationship to mathematical models of optics and refraction. Another subproject is concerned with developing methods of inference over network structures that will permit us to incorporate the results of clinical experience with different groupings of case-types into the models of consultation, aiding at the same time in the evaluation of the programs.

b) Modeling of Belief Systems and Common-Sense Reasoning

During this period a major achievement was the development and implementation of the AIMDS system. This is an MDS-based system that is specialized and augmented for use in modeling reasoning about actions. A noteworthy aspect of the system is the use of the MDS concepts of Consistency Conditions and Residues to guide frame instantiations and the drawing of further inferences from such frame instantiations.

The BELIEVER theory is a psychological model of the processes involved in the interpretation and common-sense reasoning about observed human actions. The AIMDS system is being constructed to provide a framework for formulating, studying and testing the BELIEVER theory. The computer system and the psychological theory are growing together, and they are strongly influencing each other's development. The domain of common-sense reasoning about actions represents a prototypical example of knowledge based reasoning. The richness of the psychological data that this theory must explain, namely, persons' linguistic descriptions and summarizations of everyday behavior, has forced us to think very carefully about how knowledge is to be represented and used. Out of this has emerged a general scheme that not only seems psychologically plausible but also appears to provide a useful framework for viewing a wide variety of problems of interpretation including medical diagnosis and theory-based interpretive problems involved in organic chemistry.

Along with the implementation of the system, we have developed the representation of the central knowledge components of the BELIEVER theory. The central common-sense concepts of Person, Plan and Act have been represented as frames. These frames are highly articulated structures which express the core assumptions of the common-sense psychological theory. By expressing these concepts as frames we have been able to provide a representation of these assumptions that can be used to guide and control the overall processes of reasoning about particular persons, plans and actions. The procedural components of the theory have been defined and are closely linked to these frames. This interplay and association between processes and highly articulated structures promises to provide a basis for strongly decomposing the knowledge of the domain. Since the interdependencies of these concepts are represented structurally rather than procedurally, the active database of our MDS-based system provides the basis for communication and cooperation between the processes that monitor these person, plan and act frames.

The definition of these central structural components together with the general system components have also provided a competence theory within which detailed predictions of the BELIEVER theory were specified. These predictions about the structure of summary protocols were tested and borne out by the data. This provides one of the few examples of the verification of predictions derived from work on the development of psychological theory using AI concepts in the process of theory formation.

c) Artificial Intelligence; Representations, Reasoning and Systems Development

Our work in this area continues to be oriented to collaboration with investigators in other Resource projects and to study of basic AI problems that are related to Resource applications. The collaborations involve adaptation and augmentation of existing AI methods and techniques to handle specific key problems identified in the application projects.

The close collaboration with investigators in the Belief Systems area has resulted this year in the development of the AIMDS System for handling problems of action interpretation of the type encountered in the domain of the BELIEVER theory. This system has provided one of the first examples of a working frame-based AI system. In addition, it has led to several important AI results, such as elucidation of the "frame problem" and unification of previous approaches to planning in heuristic problem solving.

Our research in language processing has led this period to two important applications - in Medical Systems and in Belief Systems. In one project, the PEDAGLOT system is being adapted to provide a natural language interface for communicating patient case histories to our glaucoma system. In a second project, PEDAGLOT is providing the basis for implementing the experimental component of a competence theory within which the BELIEVER theory can be evaluated. Empirical work in this area requires the ability to process summaries and other natural language data.

In the basic component of our work on language processing, we continued to develop a language inference system based on a "developmental paradigm" for grammar acquisition. We made progress in the area of coalescing rules of hypothesized grammars, and we started to look into ways of using semantic information to guide the hypothesis formation process.

In another project, which is also focusing on hypothesis formation, we are studying processes of computer assisted acquisition of domain knowledge from empirical data, where knowledge is in the form of weighted production rules. This type of knowledge can be represented as a stochastic graph. This year we obtained several new results in this area. We explored the implications of these results with the help of an experimental program which constructs a stochastic graph from empirical data. Also, we wrote a program which makes use of a file of graph-structured knowledge to make decisions about a domain.

In our work on theory formation in programming, we developed a formation strategy which combines a global, model-guided, approach with a local analysis of special cases. In order to study experimentally this strategy, we are now developing a system for acquiring and handling information about programs in various stages of specification, as well as other knowledge which is relevant to the formation task.

During this period we made important progress in building a strong basis of AI languages for our work. The UCI-LISP and FUZZY programming languages were adapted to the RUTGERS-10 and they were further improved. The availability of these languages made possible the implementation of major parts of AIMDS over a relatively short period of time. Work has now started on exploring the use of

FUZZY (including its features for effective use of incomplete and/or uncertain knowledge) and AIMDS in certain problems of medical decision making.

2. AIM Workshop

The Second AIM Workshop took place June 1 to 4, 1976 near the Rutgers campus, and it was attended by about 150 participants. The program included reviews of recent AI developments in Medicine, Biochemistry and Psychology; lectures and panel discussions on knowledge representation and AI system design; papers summarizing recent AI work in other application areas (outside AIM); and presentations of current research on computer-based biomathematical models. The Workshop included panels on networking and shared resources; in addition, there were a number of informal meetings in which specific projects or issues were discussed in depth. Hands-on experimentation and demonstration of AI systems (which were accessed via TYMNET and ARPANET) were an important feature of the Workshop. All indications are that the Workshop was very effective in stimulating scientific interactions and in disseminating work being done in the area of AIM.

In support of the AIM Workshop series we devoted considerable effort this period to systems development, to related computer and networking enhancements, to preparation of proceedings for the first Workshop, and comprehensive supporting documentation for the second.

A panel on Applications of AI to Science and Medicine was organized for the week following the Second AIM Workshop at the National Computer Conference in New York. It was intended to further augment the dissemination activities of AIM by bringing to a wide audience of professionals in the computer field recent developments in the AIM community.

D) Up-to-Date List of Publications

Amarel, S. and Kulikowski, C. (1972) "Medical Decision Making and Computer Modeling, Proc. of 5th International Conference on Systems Science, Honolulu, January 1972.

Amarel, S. (1974) "Inference of Programs from Sample Computations", Proc. of NATO Advanced Study Institute on Computer Oriented Learning Processes, 1974, Bonas, France.

Amarel, S. (1974) "Computer-Based Modeling and Interpretation in Medicine and Psychology: The Rutgers Research Resource", Proc. on Conference on the Computer as a Research Tool in the Life Sciences", June 1974, Aspen, by FASEB; also appears as Computers in Biomedicine TR-29. June 1974, Rutgers University, also in Computers in Life Sciences. W. Siler and D. Lindberg (eds.), FASEB and Plenum, 1975.

Amarel S. (1976) Abstract of Panel on "AI Applications in Science and Medicine" in 1976 National Computer Conference Program, N.Y., June 7-10, 1976.

Bruce B. (1972) "A Model for Temporal Reference and its Application in a Question Answering Program", in "Artificial Intelligence", Vol. 3, Spring 1972.